Edaphic Controls of Fine-Root Turnover Differ Between Pine and Poplar

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Introduction

Fine-root production and turnover are highly dynamic processes. Environmental factors such as soil moisture and nutrient content have important controls over fine-root dynamics. Prevailing opinions describe a negative relationship between root production and resource availability. Yet there is considerable controversy about even the direction of the response (Hendricks et al. 1993). In reality, the response to resource availability will likely depend on the level of resource availability, interactions among resources, the species considered, and other root characteristics (Anderson et al. 2003; Coleman et al. 2000; Eissenstat et al. 2000; Kern et al. 2004).

This experiment considers fine-root dynamics of two contrasting forest tree species grown with interacting irrigation and fertilization treatments to test the following hypotheses:

Hypothesis 1. Fine roots of different tree species will respond to water and nutrient availability in a consistent manner.

Hypothesis 2. Fine-root production and turnover will decrease with increasing resource availability

Overview of Savannah River study site

Minirhizotrons digital image collection

Methods

Site Description and Experimental Design.

Location: U.S. Department of Energy Savannah River Site near Aiken, SC (for details see Coleman et al. 2004).

Soil: Predominately a Blanton sand. We chose a site with deep sandy soil and low endemic soil moisture and nutrient levels to assure responses to water and nutrient amendments.

Plots: half-acre in size planted with *Populus deltoides* and *Pinus taeda* in 2000

Design: Randomized complete block factorial design. Species analyzed separately.

Treatments: Control, irrigation, fertilization, and combined irrigation + fertilization, applied through a drip irrigation system.

- 551 mm additional water applied to irrigated plots per year.
- 40, 80, and 120 kg N ha^{-1} yr^{-1} applied in 26 weekly applications during years 1, 2, and 3, respectively. Fertilizer increased annually to correspond with demand of growing trees.

Minirhizotron Techniques

- Root (< 2 mm diameter) were monitored to a vertical depth of 105 cm
- 5 tubes per plot
- Observed monthly collecting micro-digital images (Bartz Technology, Santa Barbara, CA).
- Quantified root length, width, condition and longevity (Rootracker, Duke University)
- Over 55,000 roots observed.

Data Analysis

- **Repeated measures** analysis used for fine-root dynamics data (SAS, Inc. Proc Mixed).
- **Survival analysis** techniques assessed root longevity (SAS, Inc. Proc Lifetest).

Results

Fine-Root Dynamics:

Seasonal oscillations were observed for standing crop, production and mortality (Fig. 1). Peak production occurred during mid-growing season, while peak mortality occurred during dormancy. Production exceeded mortality by several fold. Fine root production and mortality, i.e. turnover, was greater in poplar than pine. Similar seasonal patterns, disparities between production and mortality for establishing stands, and species differences have been reported at other locations (Coleman et al. 2000; Kern et al. 2004, Pregritzer et al. 2000).

Fine root response to treatments differed between species (Fig. 1). For poplar, highest production and mortality were observed in the combined irrigated and fertilized treatment, but for pine highest production and mortality were observed in the untreated control. In both species, the irrigated only treatment showed lowest production and mortality.

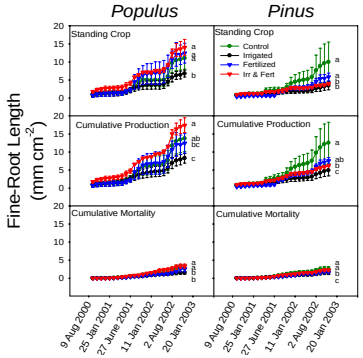

Figure 1. Species and treatment comparison of fine-root standing crop, cumulative production and mortality during three growing seasons.

Survival Analysis

Survival analysis provided further insight into treatment by species effects on turnover. Stepwise regression showed depth in soil had the greatest control over fine-root survival.

Stepwise regression: Factors ranked by amount of variation explained

Cottonwood:
Depth > Season > Year > Treatment > Diameter

Pine:
Depth > Diameter> Year> Treatment > Season

Depth explained more than 75% of the variation in fine-root survival (Fig. 2). Lower lifespan, and therefore greater turnover, is observed at the surface in both species. Short fine-root lifespan and rapid surface turnover is consistent with other studies (Coleman et al. 2000; Kern et al. 2004; Hendrick & Pregitzer 1996; Wells et al 2002).

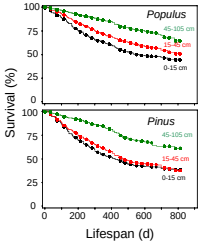

Figure 2. Fine-root survival as affected by depth and species.

Resource availability treatments explained little overall variation in survival (< 4%). However there were important species differences appearing as depth-by-treatment interactions (Fig. 3). At the surface, greatest survival was observed for untreated *Populus* and lowest survival for untreated *Pinus* . At depth, lowest survival was observed for untreated *Populus* and greatest survival for untreated *Pinus* .

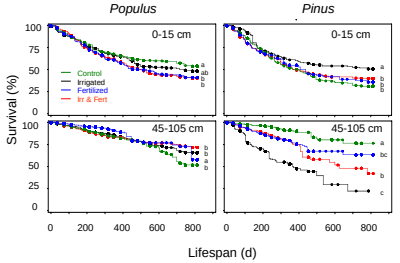

Figure 3. Depth by treatment interactions in fine root survival for both species.

The contrasting depth-by-treatment interaction between species suggest there are important drought adaptation in these differing forest tree species. Previous reports consider resource availability responses of fine-root to be unidirectional (Hendricks et al. 1993; Keyes & Grier 1981; Pregitzer et al. 2000). However our results show the direction of response to resource availability depends on depth. In a previous report we demonstrate that the direction of response also depends on the amount of resource availability (Kern et al. 2004).

Aknowledgments

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Conclusion

- The first hypothesis was rejected. Fine-root responses to water and nutrient availability differed between species.
- The second hypothesis was partially accepted.
  - Irrigation decreased fine-root production and mortality in both species.
  - Nutrient availability decreased fine-root production and mortality, except in combination with irrigation in *Populus.*
  - The response of fine-root survival to resource availability depended on depth.
- The interaction of fine-root survival to resource availability with changing depth suggests dynamic responses are more complex than currently assumed.
- Interacting factors must be identified and accounted for when investigating fine-root responses to resources availability.